

EXHIBIT D

Exhibit B (Supplemental)

U.S. Pat. No. 8,407,273
Claim 53

'273 PATENT

53. A **device**:

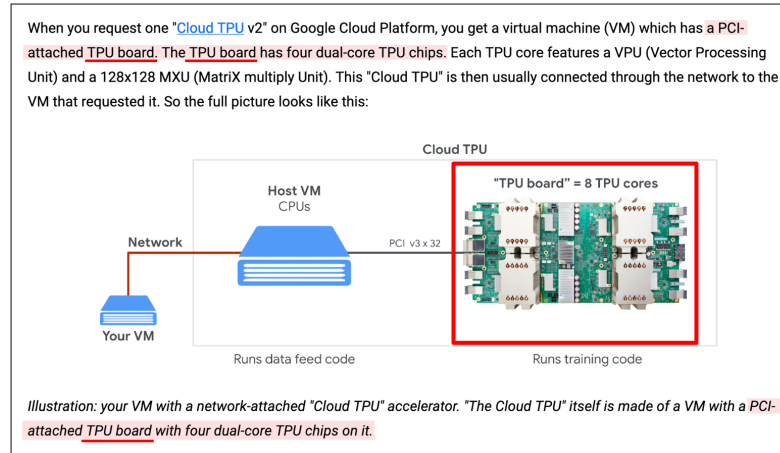
comprising at least one first low precision high-dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value,

wherein the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least $X=5\%$ of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least $X\%$ of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least $Y=0.05\%$ from the result of an exact mathematical calculation of the first operation on the numerical values of that same input;

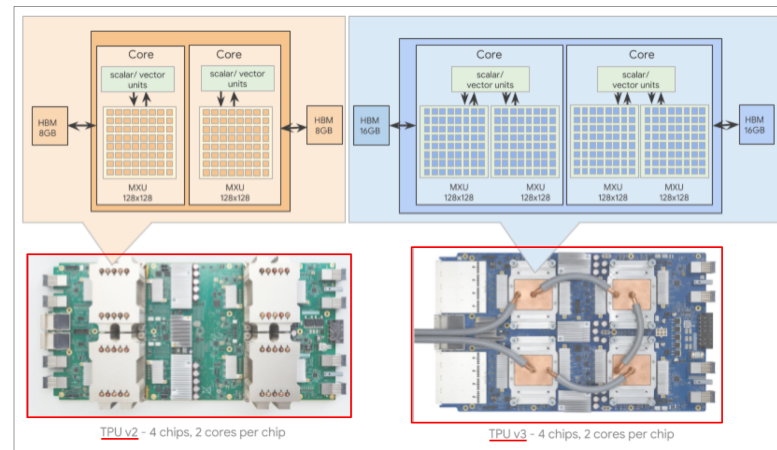
wherein the number of LPHDR execution units in the device exceeds by at least one hundred the non-negative integer number of execution units in the device adapted to execute at least the operation of multiplication on floating point numbers that are at least 32 bits wide.

SUPPLEMENTAL INFRINGEMENT EVIDENCE

As demonstrated below, the Accused Products include multiple components that, separately and independently, meet all the requirements of the claimed "device.":



<https://codelabs.developers.google.com/codelabs/keras-flowers-convnets/#2>



<https://cloud.google.com/tpu/docs/system-architecture>

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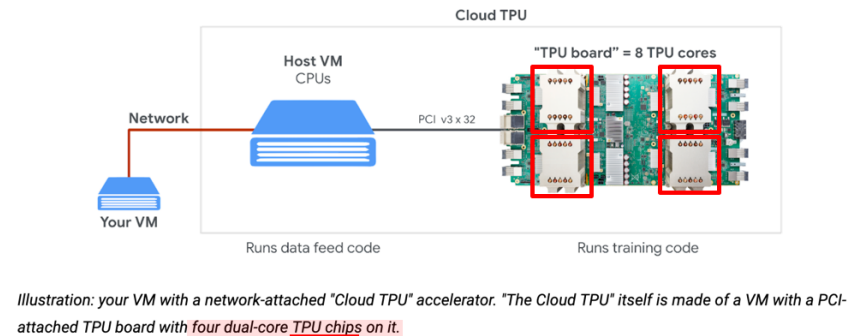
wherein the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least $X=5\%$ of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least $X\%$ of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least $Y=0.05\%$ from the result of an exact mathematical calculation of the first operation on the numerical values of that same input;

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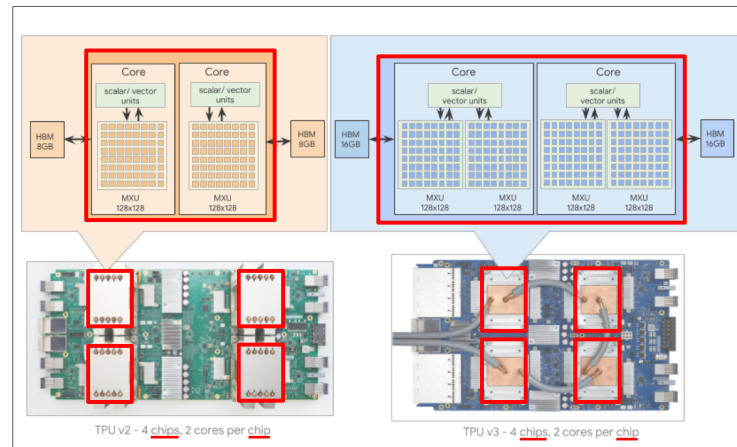
SUPPLEMENTAL INFRINGEMENT EVIDENCE

As demonstrated below, the Accused Products include multiple components that, separately and independently, meet all the requirements of the claimed "device." For example, a "TPU Chip" satisfies these requirements:

When you request one "Cloud TPU v2" on Google Cloud Platform, you get a virtual machine (VM) which has a PCI-attached TPU board. The TPU board has four dual-core TPU chips. Each TPU core features a VPU (Vector Processing Unit) and a 128x128 MXU (Matrix multiply Unit). This "Cloud TPU" is then usually connected through the network to the VM that requested it. So the full picture looks like this:



<https://codelabs.developers.google.com/codelabs/keras-flowers-convnets/#2>



<https://cloud.google.com/tpu/docs/system-architecture>

See also generally Norrie et al., "Google's Training Chips Revealed: TPuv2 and TPuv3" (Presented at HotChips Conference, Aug. 2020)

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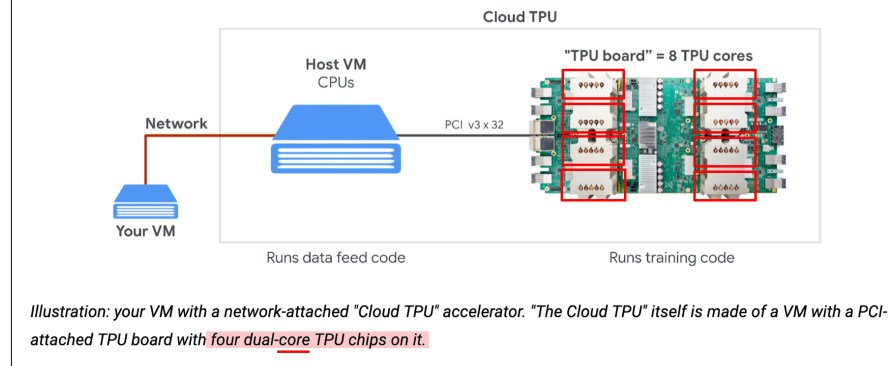
wherein the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least $X=5\%$ of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least $X\%$ of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least $Y=0.05\%$ from the result of an exact mathematical calculation of the first operation on the numerical values of that same input;

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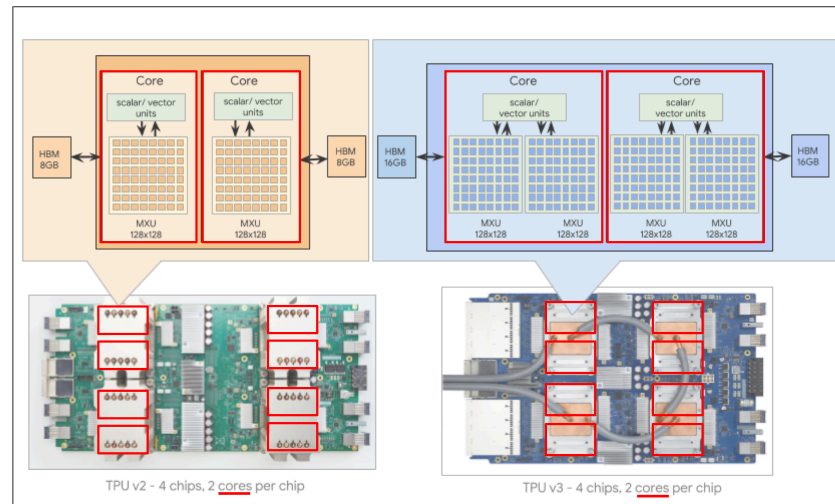
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As demonstrated below, the Accused Products include multiple components that, separately and independently, meet all the requirements of the claimed "device." For example, a "TPU Core" satisfies these requirements:

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<https://cloud.google.com/tpu/docs/system-architecture>

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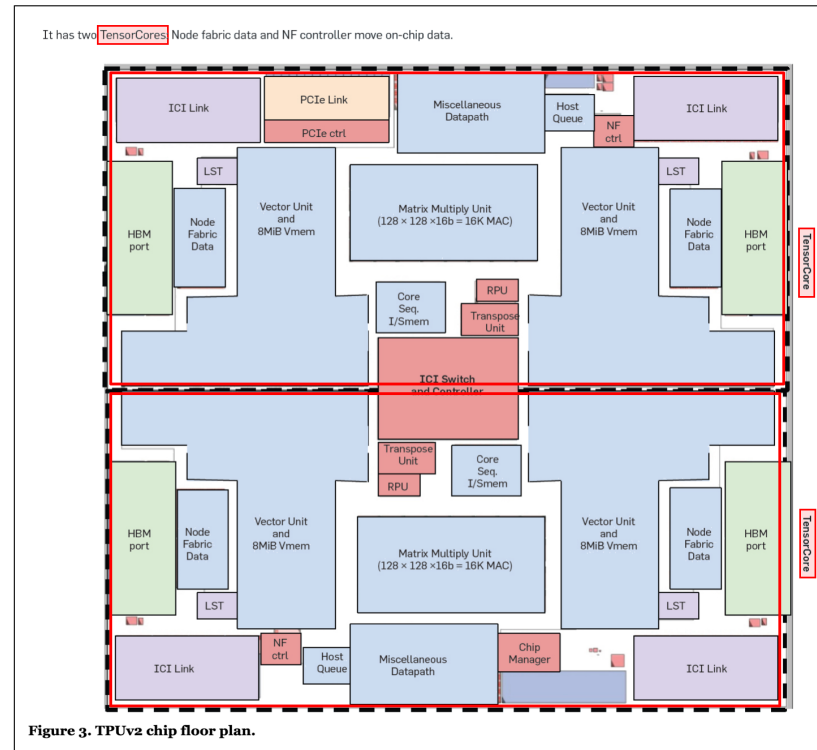
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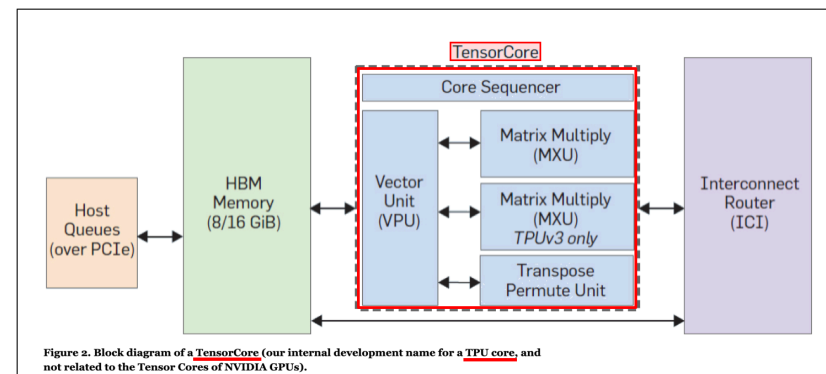
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SUPPLEMENTAL INFRINGEMENT EVIDENCE



<https://cacm.acm.org/magazines/2020/7/245702-a-domain-specific-supercomputer-for-training-deep-neural-networks>



Id.

See also GOOG-SING-SC-000001-454.

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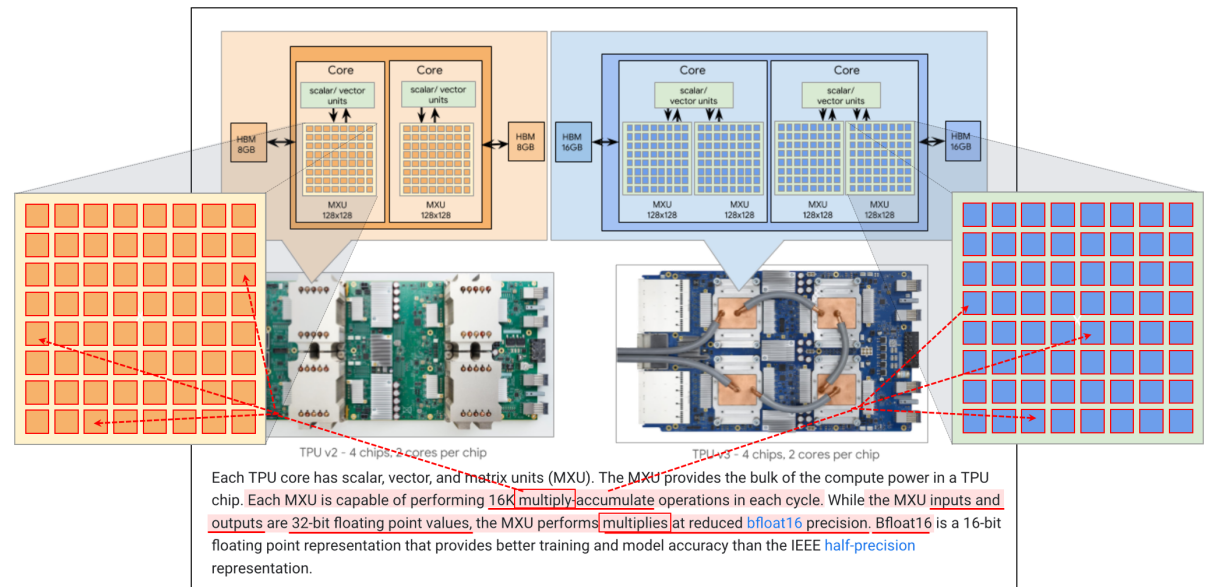
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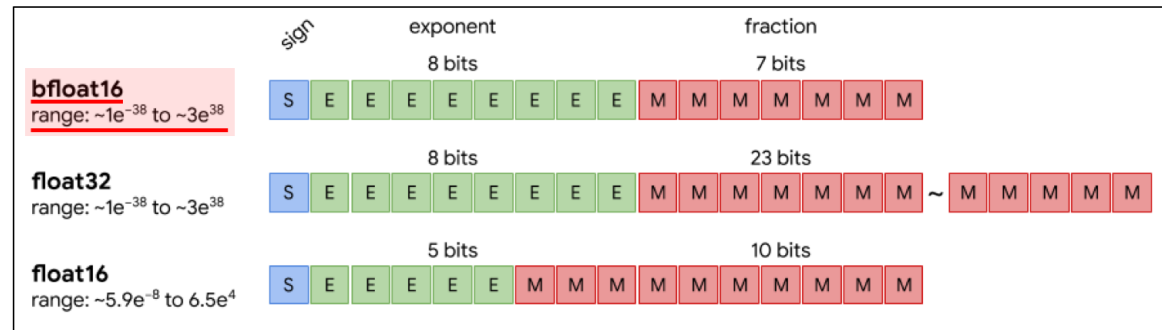
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SUPPLEMENTAL INFRINGEMENT EVIDENCE



<https://cloud.google.com/tpu/docs/system-architecture>



<https://cloud.google.com/tpu/docs/bfloat16>

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Systolic array

The MXU implements matrix multiplications in hardware using a so-called "systolic array" architecture in which data elements flow through an array of hardware computation units. (In medicine, "systolic" refers to heart contractions and blood flow, here to the flow of data.)

The basic element of a matrix multiplication is a dot product between a line from one matrix and a column from the other matrix (see illustration at the top of this section). For a matrix multiplication $Y=X*W$, one element of the result would be:

$$Y[2,0] = X[2,0]*W[0,0] + X[2,1]*W[1,0] + X[2,2]*W[2,0] + \dots + X[2,n]*W[n,0]$$



Illustration: the MXU systolic array. The compute elements are multiply-accumulators. The values of one matrix are loaded into the array (red dots). Values of the other matrix flow through the array (grey dots). Vertical lines propagate the values up. Horizontal lines propagate partial sums. It is left as an exercise to the user to verify that as the data flows through the array, you get the result of the matrix multiplication coming out of the right side.

<https://codelabs.developers.google.com/codelabs/keras-flowers-convnets/#2>

See also GOOG-SING-SC-000001-10, 13-30, 33-61, 228-292, 315-373, 396-444, 449-454.

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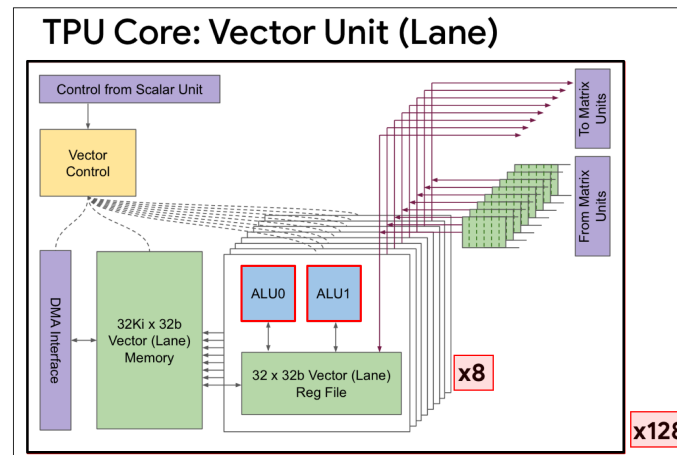
The Accused Products independently meet this claim limitation for each “device” identified above:

We cannot reveal technology details of our chip partner. Although it is in a larger, older technology, the TPUv2 die size is less than 3/4s of the GPU. TPUv3 is 6% larger in that same technology. TDP stands for Thermal Design Power. The Volta has 80 symmetric multiprocessors.

Feature	TPUv1	TPUv2	TPUv3	Volta
Peak TeraFLOPS/Chip	92 (8b int)	46 (16b) 3 (32b)	123 (16b) 4 (32b)	125 (16b) 16 (32b)
Network links x Gbits/s/Chip	--	4 x 496	4 x 656	6 x 200
Max chips/supercomputer	--	256	1024	Varies
Peak PetaFLOPS/supercomputer	--	11.8	126	Varies
Bisection Terabits/supercomputer	--	15.9	42.0	Varies
Clock Rate (MHz)	700	700	940	1530
TDP (Watts)/Chip	75	280	450	450
TDP (Kwatts)/supercomputer	--	124	594	Varies
Die Size (mm ²)	<331	<611	<648	815
Chip Technology	28nm	>12nm	>12nm	12nm
Memory size (on/off-chip)	28MiB/8GiB	32MiB/16GiB	32MiB/32GiB	36MiB/32GiB
Memory GB/s/Chip	34	700	900	900
MXUs/Core	1	1	2	8
MXU Size	256x256	128x128	128x128	4x4
Cores/Chip	1	2	2	80
Chips/CPU Host	4	4	8	8 or 16

Table 3. Key processor features.

<https://cacm.acm.org/magazines/2020/7/245702-a-domain-specific-supercomputer-for-training-deep-neural-networks/fulltext>



Norrie et al., “Google’s Training Chips Revealed: TPUv2 and TPUv3”
(Presented at HotChips Conference, Aug. 2020)

See also GOOG-SING-SC-000001-454.